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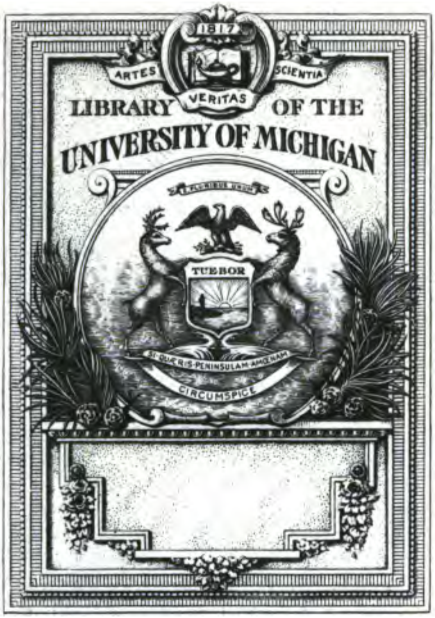

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LONDON, 1883

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ON THE

FOOD OF FISHES

BY

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DR. F. DAY

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International Fisheries Exhibition,
LONDON, 1883.

CONFERENCE ON THURSDAY, JULY 12, 1883.

Prof. HUXLEY in the Chair.

ON THE FOOD OF FISHES.

IN compliance with a request from the Committee to communicate a Paper on the Food of Fishes to the Fisheries Conference, I have thrown together a few notes upon this vast and interesting but complicated subject. For when one commences to investigate this question, it is found to branch off into many directions, and the inquirer has to consider the locality where the fish reside, whether marine, estuary, or in the fresh waters, as well as the description of the food on which it exists. And as researches are pushed further, it is found necessary to institute an exhaustive inquiry, not only into the nutriment made use of by each of these various classes of fishes, but likewise into what is necessary for the young in their different stages of growth, and in the same fish as it attains maturity.

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When the description of food most suitable to each kind has been discovered, it becomes desirable to ascertain what influences there are which tend towards the development of this food or else injuriously affect either its abundance, growth, or distribution. Some valuable forms of fish depend for their subsistence on food which may be

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found to be liable to injury or destruction, and it would manifestly be undesirable to cultivate such, if other species, equally suitable, and which subsist upon food which is practically inexhaustible in amount are obtainable. And this leads us to the conclusion that augmenting the number of fish, unless their food is proportionally increased, or it was originally in excess of demand, would be an error; for neither growth nor health could be present if the fish were being practically starved. Unless we have ascertained what nutriment is essential to the various forms of our sea-fishes, it would seem that we are scarcely in a position to understand their migrations or to legislate upon their requirements.

When we examine into who there have been in Great Britain and Ireland that have investigated into the question of the food of fishes, we find but few original observers. Among these I would especially mention Knox, Goodsir, W. Thompson, McIntosh, Dunn of Mevagissey, and Sim of Aberdeen. But however interesting and instructive isolated facts may be, and of these we have many, our fisheries require exhaustive investigations, such as have been carried out in the United States and some of the kingdoms of Europe. Among the last words penned by my old friend and fellow-student Frank Buckland I find the following: "We know, moreover, as yet but very little of the food of these" (sea) "fishes, of what it consists, how, when and where grown, obtained," &c.

For the purpose of efficiently carrying out this much-needed inquiry the investigator ought, in the case of marine fishes, to be, if possible, present when the fish is captured, noting the distance from the shore, the depth of the water, the temperature, and the nature of the ground over which he is sailing. And after the species has been secured, it ought to be correctly determined, and the stomach with its contents at once placed in spirit or other suitable preservation for further microscopic investigation, as, in many species, decomposition sets in with great rapidity, and all trace of the more delicate food becomes rapidly destroyed.

Having ascertained what minute forms or other descriptions of life are employed for the nourishment of the fish, the inquiry branches off into what it is that governs and controls migration of these forms, as currents, soils, temperature, atmospheric vicissitudes, or some more minute food upon which they themselves subsist; what are their enemies and their friends, and the conditions which favour the presence or absence of either class?

Fishes may for convenience' sake be divided into predacious, omnivorous, and herbivorous species, which necessitate an organisation suitable for each. Some are rapid swimmers in order to overtake prey, or escape from their foes; others, which obtain their food by means of stratagem, are constructed for a slower mode of progression. But, for two reasons, I must omit the consideration of form; first, because such are familiar to my hearers, and have representatives among the collections shown in this Exhibition; and secondly, because such would unduly lengthen my paper. The various descriptions of teeth in fishes are more or less demonstrative of the great difference which must exist as to the food they consume: some being prehensile, in order to assist in capturing and retaining their prey; others are more rounded for the purpose of crushing the shells upon which they mainly subsist. In carp the teeth are restricted to the throat, but the variations are too numerous to enter upon in this place.

The commencement of the alimentary canal, or the mouth, is the common receptacle of water passing to the gills for respiration and food transmitted to the stomach for nutrition, while, as might be anticipated, its capacity is large and variously formed. But the several purposes to which the mouth is employed, and the means by which such are effected, it is not my purpose to enter upon at present, except to remark on the absence of the salivary glands, which, in some forms, seem to be represented by mucous follicles that open into the mouth below the side of the tongue. Also that among the carp-like fish the palate is very sensitive, exceedingly vascular, while from numerous small pores mucus of a solvent character exudes, apparently to assist the digestion of food which the pharyngeal teeth are masticating. The gastric portion consists of an œsophagus and a stomach, between which a cardiac constriction is not so frequently observable as a change in the structure of lining mucous membrane. In some fishes there hardly exists any definite line of demarcation between the lower end of the stomach and the commencement of the small intestines, but in many a constriction occurs to this situation, termed the pylorus, which subsequently I shall have to refer to. Occasionally the stomach is situated not in the direct course, but to one side, as it were, of the intestinal canal. A second constriction, marked internally, by a more or less well-defined internal valve, shows where the small intestines terminate and the large ones begin.

If the intestinal canal is slit up and its inner surface examined, the commencement of the stomach is generally observed to be defined by increased vascularity and a more delicate lining membrane than that existing in the œsophagus. Its upper or cardiac orifice is usually larger than its lower or pyloric one, while the form of the entire organ is subject to considerable modification, being usually found in one of the two following divisions: the *siphonal,* which somewhat resembles a bent tube, as seen in the lump-sucker, flounder, salmon, carp, sturgeon, and most of the plagiostomes; and the *cæcal*, in which it ends in a blind sac, and the pyloric portion is continued from its right side, as observed in the perch, gurnard, weevers, John Dory, whiting, &c. An intermediate or transitional form sometimes exists, as in the sea-scorpion or the turbot, irrespective of which certain deviations occur which it is not my purpose to enlarge upon. The Indian *Sciæna*, erroneously termed whiting (*Johnius*), has the pyloric portion of its stomach muscular, but this augmented thickness of the muscular coats may be best perceived in the mullets (*Mugil*), in which the cardiac portion is continued downwards into a blind sac, while the pyloric portion is thickened like the gizzard of a bird, appearing as a rounded or conical projection externally, and which when cut into is found to consist of thick muscular walls, the small cavity remaining internally being lined with a thick and horny epithelium. This gizzard-like stomach is evidently employed for grinding up hard food, and it is curious to observe how, when some freshwater forms select hard substances for their diet, the coats of their stomachs may likewise become thickened. Thus in the gillaroo trout we find the ascending or pyloric portion of the stomach thickened, due to their existing upon shell molluscs in some of our fresh waters, but which thickening is lost when they become transferred to other localities, as may be seen in a specimen on the table, which died last month in our Aquarium, and which was reared by Mr. Capel from eggs procured in Ireland from the true gillaroo.

Through the pyloric orifice, partially-digested food reaches the commencement of the small intestines, and as a rule we observe that the distance from the pylorus to the vent is shorter in fishes than in most of the higher vertebrata. But the length of the intestinal tract differs in various classes, while its lining membrane is by no means of the same description in all. In the salmon or herring we find the length of the intestines shorter than that of the body, but in the former the intestinal lining membrane is raised into transverse folds, thus increasing the extent of their secreting surface, which is also further augmented by the presence of numerous cæcal appendages, as I shall have presently to allude to. In the herring, again, the cæcal appendages are numerous. In other forms we find the intestines themselves convoluted, thus increasing their length, and this is well seen among the carps, especially in such as are herbivorous forms. In the salmon the folds of the internal lining of the intestines increase in size, decrease in number, and become less oblique as they approach the rectum, and, as observed by Owen, the commencement of the large intestine is marked by a large transverse fold or circular valve, which is succeeded by several others less produced, and resembling the *Valvulæ conniventes* in the human jejunum. This large intestine may be straight, as seen in the sturgeon or chimæra, &c., where the transverse folds (as observed existing in the salmon) become continuous, and there is formed an uninterrupted spiral valve, also present in the sharks, the rays, and their allies, but which may be modified into transverse coils.

It is thus that in fishes economy of space is effected by an increase of the secreting and absorbing surface of the vasculo-mucous membrane lining the intestinal tract, whether such be merely raised into puckers, or these puckers be continued into transverse folds, or even forming a circular uninterrupted spiral valve or coil to the large intestine.

An examination into the cæcal appendages, also termed pyloric cæca, and pyloric appendages—what forms possess, and what are deficient in them—under what circumstances they vary—and, lastly, what are their functions? have always appeared to me to be questions respecting which much still remains to be ascertained. One constantly sees observations respecting these organs and their importance, but one rarely finds remarks as to what *rôle* they subserve in the economy of fishes. One author divides species by the number of appendages they possess. Another tells us that they may be considered as lateral prolongations of the intestines, into which food does not enter, and the secretion which comes from them is similar to that of the intestinal mucous membrane. Some consider these appendages to be a modified pancreas, while a very rudimentary form of this organ has been detected as a minute glandular body, terminating in a duct, which opens by from one to three orifices into the intestines, close to the bile duct, but occasionally so closely attached to the latter as to be easily overlooked. It is seen both in fishes which possess pyloric appendages, as perch, cod, salmon, sturgeon, and also in such as are deficient in them, as brama, gar-pike, pike; while the sharks and rays are furnished with a reddish-yellow and lobulated gland, which is more similar to what is perceived in the higher forms of vertebrate animals. In short, we may find both a true pancreatic gland and cæcal appendages existing in the same fish.

What are the common appearances of cæcal appendages? If we commence our investigations among the osseous fishes, we see in some one or more small ducts, each ending externally in a blind extremity; these either surround the commencement of the intestine just beyond the pyloric or lower end of the stomach, or else spring from one of the sides of the first part of the small intestine, along which they may be continued for some little distance. We find in a single fish from one to upwards of a hundred of these cæcal appendages, each of which may open by a separate orifice into the intestinal canal, or two or more conjoining form a common duct, and thus diminish the number of openings. In the sword-fish (*Xiphias*), all the various appendages conjoin with the common tubes which empty their contents into the intestines. Passing from the osseous upwards to the cartilaginous, or semi-cartilaginous fishes of the ganoid sub-class, we still find this gland present. Thus in the sturgeon (*Acipenser*), a mass of areolar tissue binds the various cæca together, forming it into a parenchymatous conglomerate gland.

Food, climate, and increased space of water, or all combined, exercise a modifying influence upon the cæcal appendages of fish; thus trout in Tasmania, reared from eggs sent from Hampshire and Buckinghamshire, have increased largely in size in their new home, augmented the number of their cæcal appendages, and are now in most respects identical in appearance with the *Salmo ferox* of our larger lakes.

Respecting our freshwater fishes, their food has been more closely investigated than has that of our marine forms, and, for very obvious reasons, the owner of a fishery, if he takes any interest in its development and success, watches whether his fishes thrive or deteriorate, and also endeavours to ascertain to what cause such may be due. Possibly his fish-ponds may be too full of small and inferior kinds, which, by devouring the food, leave but an insufficient supply to the more valuable table sorts. Maybe the food itself is deficient in quantity or nourishment. But all these questions fall so naturally to the freshwater fisheries, which have been so elaborately brought before this Conference, while that of salmonidæ will doubtless be fully discussed by Her Majesty's assistant inspector of salmon fisheries, whose Paper immediately succeeds the one I have the honour to read before you, that I have purposely omitted reference to freshwater and anadromous species, confining my remarks as much as possible to marine forms, and those most suitable as food for man.

If only by the knowledge of what is required, combined with care and attention in carrying such out, can the management of private ponds be made successful by the fish culturist ; if leaving them to chance, and withdrawing control, eventuates as completely in their ruin as it would to leave arable lands to be self-sown, such only leads us to consider whether, in time, the same want of judicious management might not have equally disastrous results upon the fisheries of lakes and rivers, although possibly at a longer interval of time. Probably among the attractions which entice inshore some of the more predaceous marine forms, are fish which have descended rivers to the sea, where they linger about the estuaries.

Respecting feeding, many forms nearly or entirely omit doing so at breeding periods, as the salmon, trout, and anadromous shad, while the herring, more or less, ceases at these times. On the other hand, pike and barbel will take food at those times. During the cold season a cessation of feeding occurs among many forms of fish. In the East it is curious to observe some of the sheat-fish, or siluroid family, wherein the male carries about the eggs in his mouth until they are hatched (examples of which are in the Indian collection in the Exhibition). If he fed at these times, the eggs would certainly be swallowed, but he does not do so, as I have convinced myself by opening many specimens, in all of which the intestines were destitute of food.

When a fish is first hatched, we see a large sac depending from its lower surface, this being the yelk or umbilical sac, in which nourishment is contained, and sustains the young for a longer or shorter period. After this food has been absorbed, the fish culturist frequently finds great difficulty in procuring suitable nourishment for his young charges.

Fishes are to a great degree highly voracious; thus, Dr. Houston showed in 1847 at the Zoological Society the skeleton of an angler *Lophius piscatorius* two and a half feet long. Inside its stomach was the skeleton of a two-feet long cod fish, *Gadus morhua*, within whose stomach again were contained the skeletons of two whiting, *Gadus merlangus*, of the ordinary size, while inside the stomach of each of these fish lay numerous half-digested bones of little fishes, which, however, were too small and too comminuted for it to be possible to identify the species they belonged to.

In warm-blooded animals a large amount of food is necessary in order to produce the high temperature of the blood, and make up for the wear of the body produced by constant motion. But in cold-blooded forms a different condition exists, in them nutriment being mostly employed for increasing the size of the animal, a much less amount of food being required to sustain the smaller wear and tear resulting from the little motion which is often perceived, especially in fresh-water forms.

In most of the shallow portions of the sea around our coast are distributed various descriptions of sea weeds. Should the bottom be rocky we find brown algæ (*Fuci*), while further out from the tide line are red algæ (*Floridi*).

But with increasing depth we observe less vegetation, or should algæ drift to sea they subside to the bottom, constituting that soft black mud seen in some of our bays, and in which worms, molluscs, crustaceans, and other marine animals have their home, and find subsistence, while they in their turn become food for fishes which rout out and consume them. Professor Mobius, at ninety to ninety-five fathoms in the Baltic, where the bottom is formed of plastic clay, found very few worms. In the Mediterranean, at the south-east of Sicily, where the bottom consists of yellowish clay, the British exploring expedition detected no trace of animal life. But in the southern portions of the North Sea, at from twenty to twenty-five fathoms, and with a muddy bottom, such is found to be alive with worms, small crustacea, snails, molluscs, echinoderms, and fish, and, as a result, with fish which prey upon them. Irrespective of the foregoing algæ found in the ocean, there may be microscopic forms so abundant as to render the surface almost turbid. Diatoms live in every sea, their remains forming the principal portion of the finer particles at the bottom, they are swallowed by pelagic animals, as salpæ, pteropods, &c., which after death subside in the waters. Likewise all rivers carry organic matter into the ocean, rendering the bottom rich in food, and a resort for invertebrate animals, and consequently fish which prey upon them. Currents which carry plants and small marine creatures from place to place, must likewise influence, through food, the migration of fish, for the temperature, salinity, and currents of the sea exercise a great influence upon animal and vegetable life.

Although the growth of fishes much depends upon the suitability and abundance of the food which they are able to obtain, other causes likewise play an important part. In some forms, as the turbot, it would appear as if they augment more rapidly in an aquarium when supplied with suitable nourishment than they do in the open sea. Thus in the Southport aquarium some about three inches across, increased in two and a half years to 10 lb. in weight, and after two years more they further augmented to 20 lb., or a yearly average in amount of 4½ lb. a fish.

In marine fisheries the question of the food upon which the various forms of fish subsist is of vital importance, as on it greatly depends whether legislation might be reasonably expected to prove useful, superfluous, or mischievous. Many forms are omnivorous, others carnivorous, and a few herbivorous. Some, like the sucking fish *Remora*, attach themselves to the bodies of whales, sharks, and larger fishes and so are carried about by their host, upon whom they do not prey, but simply use him as a means of conveyance, and these are termed commensals. Others, as the borer or hag, *Myxine glutinosa*, is a true parasite, attaching itself to another fish, into which it bores and devours, subsequently passing on to fresh victims. Some fishes, as the pilot fish, *Naucrates ductor*, or the black fish *Centrolophus pompilus*, would seem to keep company with whales, sharks, sun fishes, and other forms, mostly for the purpose of subsisting upon the parasites which infest these larger species, or to obtain their excrementitious dejections. The lamprey, besides attacking living fish, likewise prey upon such as are in an advanced stage of putrefaction, and many forms will not only devour the eggs and young of their neighbours, but likewise those of their own species. In a sturgeon's stomach Thompson observed several examples of minute crustaceans (*Amphipoda*), the remains of shrimp-like forms, fragments of *Porphyra*, which had probably been growing on the sandy bottom of the sea, and a perfect, but minute *Tellina tenuis;* it likewise contained some fine sand, with which the intestines were wholly filled. The *Polyodon* *folium* of the Mississippi is supposed by fishermen to feed upon the mud and slime at the bottom of the river, but is found to consume an enormous amount of entomostraca, while fully one-fourth of its food is composed of vegetable algæ, which are obtained by means of its long and double row of fine gilt rakers, forming a strainer, which permits the passage of the fine silt of the river, but arrests everything else as large as a cyclops. In the New South Wales section of this Exhibition may be seen the teeth in the jaws of a shark, *Heterodontus galeatus*, stained of a pinkish purple, due to its feeding largely on an Echinoderm common in Port Jackson, the *Centrostephanos rodgersii*, which stains them of that colour. This tempting morsel has spines about three inches long, and must be a very prickly subject to swallow. The spines of other Echinoderms, *Amplypneustes ovem* and *Strongylocentrotus erytherogrammus* have also been found in the intestinal tract of this fish. The torpedo, or cramp fish, paralyses its victim.

The colours of fish may be dependent upon the food on which they subsist; thus Professor Mobius found in the stomach of some cod large pieces of two marine plants, *Ulva lactaca* and *Zostera marina*, irrespective of. shells, snails, crabs, and fishes. These had affected the external colour of the cod, and thus became indicative of the depths at which they live; these variations comprised white, yellowish brown, speckled, green, and black. The same change of colour, induced by alterations in food, has been observed at Sir James Gibson Maitland's trout ponds at Howietown, near Stirling.

Some fishes feed at night-time, others during the day; while what is eaten when in captivity is not invariably a criterion of what they consume when in a state of nature. Thus in Ireland cod fish and haddock kept in vivaria have been said to prefer boiled potatoes to every other description of food.

For the purpose of illustrating upon what marine fishes subsist, I have deemed it advisable to select classes which are most useful to man. The sea fisheries for practical investigations may have their finny inhabitants (as already remarked) divided into: (1) such as generally reside in or near the surface of the sea; (2) such as swim in moderate depths or at the bottom, and (3) lastly, those which are ground feeders. It is evident that unless the food which all subsist upon is identical, and that such is found at all the various depths which these different fishes inhabit, what causes would be injurious to the food partaken by one class may be perfectly innocuous to that which the other classes live upon. The whelk, *Buccinum*, and the mussel, *Mytilus*, at the bottom may be consumed by bottom feeders, but they would not afford sustenance to herrings which mostly frequent the upper strata of our seas, where they prey upon small crustacea and other forms of food. The ground feeder, as the sole, turbot, or brill live on what is normally present at places they frequent; anything which tends to injure the various kinds of animal life found at these places must tend to destroy what would be food for fishes.

The heads for a brief investigation may be divided into what is the food of the more gregarious kinds of fish, as of the mackerel, herring, or pilchard, forms which when investigating the subject of their food ought to be kept essentially distinct from the more sedentary and local residents. And in tracing this question of food it will be best to proceed from the more predaceous to the more preyed upon fishes. Sharks and their allies follow shoals of the herring family, as I had the opportunity of investigating off the western coast of India, where on the disappearance for several successive seasons of the oil sardine, sharks, saw fishes and skates were absent, while all these forms returned simultaneously. We see also on our coasts the strong follows the weak, and preys upon him if a sufficiently dainty morsel.

The mackerel, it has been observed, swim higher or lower in the water in accordance with atmospheric vicissitudes, most probably due to the influence of such upon the food they subsist upon. Thanks to Mr. Dunn, of Mevagissey, I have had the opportunity of investigating the food consumed by the mackerel at various seasons of the year, when I was not able to be on the coast: in the summer and autumn they follow the herring and take heavy toll, especially during the later months of the year, of the britt, which are the fry of those fishes and of the sprat. About the middle of May along the south coast they are especially partial to the mackerel midge, which is the young of rockling (*Motella*). They also prey upon small crustacean forms. In March, 1882, the contents of the stomach of some of these fishes, sent me from Mevagissey and which had been captured eight miles from land over forty fathoms of water, consisted of small crustaceans *Thysanopoda Couchii*, which form was originally procured by Couch in a similar manner. In May, 1880, I opened a number from the south-west coast, all were gorged with ova. In May, 1883, Mr. Dunn found Mevagissey Bay swarming with entomostraca, and similar animals were present in the stomachs of the mackerel and pilchards. These copepods consisted of *Centropages typicus*, Kröyer; *Temora longicaudata*, Lubbock; *Calanus Finmarchicus*, Gunner (A. Norman). Mackerel consume other fish, following the herring and their young, the fry of the rockling, various forms of crustacea, also of ova, and in fact prey upon a large amount of animal food, while it again is pursued by the tunny, the sharks, dog-fishes, and other forms stronger than itself.

The herring, so valuable to the fishermen of these islands, is another gregarious form, appearing and disappearing from some places in a way often inexplicable to the fishermen. If, however, an investigation were made, it is probable that their seemingly eccentric movements may be caused by the appearance or diminution of some peculiarly acceptable description of food on which they subsist : this is generally held to consist of minute shrimp-like crustacea, often of forms belonging to the same division as the common *Cyclops* of our fresh waters. But it is also evident that it feeds upon very varied forms of animal life, and probably is not particular what it is, providing it can obtain sufficient. In February, 1882, I found that some sent me by Mr. Dunn, from Mevagissey, had been feeding upon annelids : from the same locality in the middle of May their stomachs were crammed with sand-launces (*Ammodytes*), some of which were up to 2½ inches in length, and as many as nineteen were inside one herring, while the sand-launces in their turn were full of the remains of crustacea. A month later from the same place and captured about eight miles off shore, the food had again changed and consisted almost entirely of the young of a very rare gobioid fish (*Crystallogobius Nilssonii*), the largest of which was 1½ inches long, there were also a few young herrings and sand-launces. At the end of May, 1883, herrings were again found to be gorged with the young of the *C. Nilssonii*, a remarkable fact, as only one adult specimen of this Scandinavian species has been recorded from the shores of the British Isles, and that was obtained by Mr. Edward, of Banff. From whence then do the herrings follow these little gobies ?

Knox obtained from the stomachs of some herrings from the deep-sea, sand-eels from one, what appeared to be young herrings from another, and other small fish. Goodsir, (*Edinburgh New Philosophical Journal*, July 1843), gave the result of his examination of the *maidre* or food of the herring in the Firth of Forth, and with which the stomachs of the fish were found to be filled. Cirripeds, Crustaceans, and Acalephæ were detected, of which crustaceans were in the largest number, and consisted of masses of *Amphipoda* and *Entomostraca.* Among the Acalepha the different species of *Beroœ* were seen in the greatest numbers. While he wrote from Austruther, in 1843, that the herrings follow the shoals of Entomostraca to prey upon them, for it is only when the latter make their appearance on this coast that the former are seen, and when the food is most plentiful the herrings are in the best condition.

Off Loffoden Sars found the sea swarming with microscopic animals, especially small crustaceans termed "herring food." They were mostly *Calanidæ* and chiefly *Calanus Finmarchicus* and *Temora longicornis.* This herring food depends for its existence on lower and smaller organisms as diatoms, while the slime of Christiania Fiord chiefly consists of such, and it also largely composes the slime of the polar seas.

H. Widegren, of Scandinavia, observes that the food of the young, as well as of the grown herring, consists chiefly of small crustaceous animals, invisible to the naked eye, which are found in enormous quantities in the sea, both in shallow and deep water, and may be detected by straining water through a cloth. "Their quantity varies at different seasons, during a change of temperature and at different depths, and this probably is the reason why these fishes are taken at different depths, in accordance with temperature or currents."

Mr. G. Sim, of Aberdeen (Edinburgh Prize Essays Fish Exhibition, 1882), found in the stomachs of those he examined, the young of their own kind, also of sprats. Of stalk-eyed crustacea, examples of *Galàthea, Mysis, Thysanoessa, Thysanopoda* and *Acanthocaris,* several larval forms of *Brachyurus,* some of which were very abundant. Of sessile-eyed crustacea, *Hyperia, Lestrigonus,* and one species of *Æga.* Of Entomostraca, *Cythere, Temora,* and *Evadne.* Of the foregoing, *Hyperia* and a young univalve mollusca, *Sagitta bipunctata* (?), *Mysis spiritus,* and young herrings and sprats formed the largest portion of their food, the last two being most abundant from December until May. From May until October, *Temora longicornis* is their most common food, and from December till February, *Hyperia galba* and *Sagitta bipunctata.* The other forms of animal life, it appeared to him, might be classed as a sort of chance food, while, although two species of sessile-eyed crustacea, *Amathilla Sabini* and *Atylus Swammerdamii,* swarmed along the coast, he never found either in the stomach of the herring. Mr. Sim points out how similar in external appearance is the *Hyperia galba* on which it feeds, to *Atylus Swammerdamii,* which it rejects, and suggests whether taste or smell may not exercise an influence.

The food of the herring varies in accordance with what most desirable form exists at the locality which it frequents, and it devotes its attention to the young of fishes, or of its own kind, or of the sprat; the young of the sand launce, and likewise of a small gobioid along our southern coast. Stalk-eyed, sessile-eyed crustacea, and entomostraca, afford it nourishment, and Acalepha have also been detected in its stomach. As it appears to exercise selection in the forms it devours as food, it is probable that it would follow such to wherever they migrate, as along our coast, or into our bays, unless their progress were checked by any extraneous causes.

Passing on next to consideration of the fishes which we possess, belonging to the cod family, what are the chief characteristics of their food? They may be found of surface and littoral forms, and along our coasts at depths rarely exceeding 120 or 150 fathoms, while the common cod, *Gadus morhua*, is noted for its omnivorous appetite. The cod will consume small fish, or the young of its own kind, or of any other that they can capture; but seem to be especially partial to sand-eels, herrings (which they will tear out of the nets), and their spawn, and sprats: while Leach found six dog-fishes inside one of these fish. Crustaceous and testaceous animals also, as is well known to fishermen, evidently prefer one kind of animal food to another, being very partial to crabs and whelks, while their digestion is so powerful that the greater portion of the shells they swallow are dissolved. Various, indeed, have been the contents of the stomach of these fishes; an entire partridge has been taken from one, a hare from another, and a black guillemot from a third; while from two others have been removed a piece of tallow candle, and a white turnip, irrespective of a bunch of keys; stones are frequently found inside these fish, having been probably swallowed in order to obtain the corallines which were attached to them, the stones being subsequently ejected. They will eat almost any kind of crab, indeed, almost any kind of animal food. Dr. M'Intosh obtained the following food from cod-fishes captured at St. Andrews.

A zoophyte, *Thelepus Lima Loscombii*, G. B. Sowerby; *Mediolaria nigra*, Gray; *Crenella decussata*, Mont.: *Nucula nucleus*, Linn.; *N. nitida*, G. B. Sowerby; *Circe minima*, Mont.; *Scrobicularia prismatica*, Mont.; *S. alba*, Müller;

Solen pellucidus, Pennant; *Chiton cinereus*, Linn.; *Trochus tumidus*, Mont.; *Turritella terebra*, Linn., a favourite food probably in many cases on account of its tenant, the hermit crab; *Trichotropis borealis*, Brod. and Sowerby (1 ex.); *Trophon truncatus*, Ström.; *Pleurotoma Trevelyana*, Turton; *Philine scabra*, Müller; *Tritonia Hombergi*, Cuv. (occasional); *Loligo vulgaris*, Lamarck; *Eledone cirrosa*, Lamarck; *Amphiura Chiajii*, Forbes; *Ophiopholis aculeata*, O. F. Müll.; *Echinoscyamus angulosus*, Leach; *Cucumaria Hyndmanni*, Thomp.; *Thyone fusus*, O. J. Müll.; *Thyonidium Dubeni*, Norman; *T. commune*, Forbes and Goodm. (1 ex.); *Priapulus caudatus*, Lam.; *Aphrodita aculeata*, Linn.; *Lepidonotus squamatus*, Linn.; *Enipo Kinbergi*, Mgrn. (occasional); *Sthenelais limicola*, Ehlers; *Sigalion Mathildæ*, M. Ed.; *Nephthys cæca*, Fab.; *N. Hombergii*, And. and M. Ed.; *N. Johnstonii*, M'Int.; *Phyllodoce grœnlandica*, Ærst.; *P. laminosa*, Sav.; *Alitta virens*, Sars.; *Lumbriconereis Lamentiana*, Grube; *Goniada maculata*, Ærst.; *Glycera capitata*, Ærst.; *G. Goësii*, Mgrn.; *Ophelia limacina*, H. Bath; *Terebellides Strœmii*, Sars; *Sabella pavonia*, Sav. Among crustacea, *Hyale Nilssoni*, H. Rath; *Anonyx Holböllii*, Kröy; *Ampelisca carinata*, Bruz.; *A. Belliana*, Bate; *Dexamine spinosa*, Mont.; *Atylus Swammerdamii*, M. Ed.; *Gammarus marinus*, Leach; *G. locusta*, Linn.; *Caprella tuberculata*, Guérin; *Eurydice pulchra*, Leach; *Arcturus longicornis*, Sow.; *Idotea tricuspidata*, Desm.; *Diastylis Rathkii*, Kröy; *Palæmon squilla*, Linn.; *Pandalus annulicornis*, Leach; *Nephrops Norvegicus*, Linn.; *Gebia deltura*, Leach; *Galathea strigosa*, Linn.; *G. squamifera*, Mont.; *G. dispersa*, Bate; *Ebralia tuberosa*, Penn.; *Hyas araneus*, Linn.; *H. coarctatus*, Linn.; *Portunus depurator*, Linn.; *P. holsatus*, Fab.; *Atelecyclus septemdentatus*, Mont.

Haddocks likewise feed near the ground, and, for their size, are as voracious as the cod; their food varies in accordance with the locality inhabited. They consume herrings, sprats, and other small fish during the warmer portion of the year, and in the winter are found to swallow stone-coated worms, *Serpulæ*, which the fishermen term haddock meat; while they will also consume shell-fish and take bait similar to those used for the cod. Dr. McIntosh obtained the following from examples of this fish captured at St. Andrews.

Pecten tigrinus, O. F. Müller; *P. similis*, Laskey; *Crenella decussata*, Mont.; *Nucula nucleus*, Linn.; *N. nitida*, G. B. Sowerby; *Circe minima*, Mont.; *Tellina pusilla*, Phillipi; *Scrobicularia prismatica*, Mont.; *S. alba*, Müller; *Solen pellucidus*, Pennant; *Chiton cinereus*, Pennant; *Trochus tumidus*, Mont.; *Trophon truncatus*, Ström.; *Pleurotoma Trevelyana*, Turton; *Philine scabra*, Müller; *Eledone cirrosa*, Lamarck; *Amphiura filiformis*, A. O. Müller (rare); *A. Chiajii*, Forbes; *Ophiura albida*, Forbes; *Echinoscyamus angulosus*, Leach; *Cucumaria Hyndmanni*, Thomp.; *Thyone fusus*, O. F. Müll.; *Thyonidium Dubeni*, Norman; *Priapulus caudatus*, Lam.; *Aphrodita aculeata*, Linn.; *Lepidonotus squamatus*, Linn.; *Enipo Kinbergi*, Mgrn. (occasional); *Travisia Forbesii*, Johnst.; *Scalibregma inflata*, Ball; *Sthenelais limicola*, Ehlers; *Sigalion Mathildæ*, M. Ed.; *Nephthys cæca*, Fabr.; *N. Hombergii*, And. and M. Ed.; *N. Johnstoni*, M'Intosh; *Phyllodoce grœnlandica*, Œrst.; *P. laminosa*, Sav.; *Lumbriconereis fragilis*, O. E. Müll.; *L. Lamentiana*, Grube; *Onuplus tubicola*, O. F. Müll.; *Goniada maculata*, Œrst.; *Glycera capitata*, Œrst.; *G. Goësii*, Mgrn.; *Ammotrypane aulogaster*, H. Rathke (occasional); *Ophelia limacina*, H. Rath.; *Eumenia crassa*, Œrst.; *Chœlopterus Norvegicus*, Sars; *Maldane biceps*, Sars; *Terebellides Strœmii*, Sars. Among crustacea, *Lysianassa* *atlantica*, M. Edw.; *Anonyx Holböllii*, Kröy.; *Callisoma crenata*, Bate; *Ampelisca carinata*, Bruz.; *A. Belliana*, Bate; *Amathilla Sabini*, Leach; *Gammarus locusta*, Linn.; *Caprella tuberculata*, Guérin; *Cirolana spinipes*, M. Ed.; *Eurydice pulchra*, Leach; *Arcturus longicornis*, Sow.; *A. gracilis*, H. Goods.; *Idotea tricuspidata*, Desm.; *Diastylis Rathkii*, Kröyer; *Pandalus annulicornis*, Leach; *Hippolyte varians*, Leach; *H. spinus*, Sow.; *Gebia deltura*, Leach; *Galathea strigosa*, Linn.; *G. dispersa*, Bate; *Pagurus lævis*, Thomp.; *Ebralia Cranchii*, Leach; *Hyas coarctatus*, Leach; *Portunus holsatus*, Fab.; *P. pusillus*, Leach.

These are forms in which the destruction of shell fish and crustacea means the deprivation to the cod family of a portion at least of their food; and, unless that food had previously been largely in excess, much destruction must eventuate in either a decrease in the quantity of nourishment for each individual fish, and which would probably cause them to become inferior in quality; or else it would have to be met by a decrease in the number of fish residing in a given space of water.

The last class I shall refer to are ground fish, *Pleuronectidæ*, as halibut, turbot, brill, soles, plaice, and other marine kinds, the food of which varies widely from that which is consumed by the gregarious surface swimmers, or the more omnivorous midwater forms. Destitute of an air-bladder, and generally with mouths comparatively smaller than exists in the more predaceous members of the cod family, we find them essentially ground feeders. Their diet consists of almost any invertebrate form, by them shell-fish and crustacea are largely consumed, as are also small fish and fish-eggs. Dr. M'Intosh, at St. Andrews, obtained the following varieties of food from flounders captured there:—*Pecten tigrinus*, O. J. Müller; *P. similis*, Laskey;

Circe minima, Mont.; *Tellina pusilla*, Phillipi; *Chiton cinereus*, Pennant; *Trophon truncatus*, Ström; *Philine scabra*, Müller, and *P. pruinosa*, Clarke (rare); *Sepiola Rondeletii*, Leach (1 ex.); *Echinoscyamus angulosus*, Leach; *Sthenelais limicola*, Ehlers; *Lumbriconereis fragilis*, O. Müll.; *Glycera Goesii*, Mgrn. Among crustacea, *Hyale Nilssoni*, H. Rath.; *Ampelisca Belliana*, Bate; *Arcturus longicornis*, Sow.; *Idotea tricuspidata*, Desm.; *Diastylis Rathkii*, Kröyer; *Hippolyte securifrons*, Norm.; *Galathea dispersa*, Bate; *Hyas coarctatus*, Leach; *Portunus pusillus*, Leach.

Around our coast, whether correctly asserted or not so, still fishermen appear to believe that our inshore fisheries are being depleted, and only last week the following remarks in the *Field* appeared from the pen of Mr. Barber, of Mevagissey:—"Long-line fishing all along our coasts is now in the ascendant, and the system of fishing with hand-lines is gradually becoming obsolete; but although a larger amount of fish is being caught than under the old system, it is evidently a most destructive method, as a great many fish which get hooked, in the death-agony twist themselves off the line with the hooks attached, and must evidently waste and die to no purpose. We believe the time is fast approaching when this system of fishing will exterminate all the conger-eels, cod, ling, ray, and skate within twenty miles of our coast, as now, to be successful, the boats have to proceed at least double that distance from shore, which seems a striking contrast when compared with the heavy hauls which were made some ten years since by hand-lines at a distance varying from five to ten miles off, where now scarcely any fish of the description mentioned are to be caught."

I must now bring to a conclusion this most imperfect sketch of the food of our fishes, a subject which, were it fully worked out, would furnish materials for volumes instead of pages. I have been forced to restrict myself to the consideration of a few carnivorous, omnivorous, and vegetable feeders as typical of what takes place in the vast community of the finny tribes. I have attempted to demonstrate that inshore fisheries, as of the haddock and its allies, may be depleted, owing to the destruction of the food on which those fish subsist, and which may have little or no connection with the food which is eaten by gregarious kinds, as the mackerel and herring, which appear at certain seasons off our shores in enormous numbers. It cannot be too strongly impressed upon those who do not personally search for their information in the homes of the fish, that although in some points injuring one set of fisheries may react upon another, still one class may be depopulated while another is but slightly affected. To argue that because large numbers of herring and mackerel are brought to market therefore all our sea fisheries must be in an eminently satisfactory state, is about as conclusive as to suppose that because sea-birds are abundant no protection is necessary for those living on the land.

While I cannot resist holding the belief that not only is the destruction of certain forms of fish food possible by man, but I think it is proved that such occurs, thus starving fisheries. The following instance may be adduced to show how their food producers have become impoverished. In some localities the mussel beds have been thrown open without restriction to every comer, and at most of such places this fish food has almost disappeared, in the remainder it is hastening to decay.

I am as averse to legislating upon fisheries without due inquiry being instituted into all their conditions as any one can be, but I cannot help thinking that one of the members of this Conference offered us a sound and well-needed warning, when he said he was equally averse to sea fishery laws which had existed for centuries being summarily abolished without, as it appeared to him, a due investigation and exhaustive inquiry having been first made into the true condition of the fisheries, fishermen, and all connected therewith.

Whilst experience would seem to point out that we must either give protection to our fishes, or replace in our waters by artificial means a number sufficient to keep up the supply. We may be doing an injury in our endeavour to effect good, for suppose no soles below a certain size were permitted to be captured, the useless little sole, *Solea minuta*, which rarely exceeds 3½ inches in length, would escape destruction. By preserving it we may be protecting a form which consumes the identical food as its relative the more valuable common sole (*S. vulgaris*), and in this manner permit it to devour what would otherwise form the food of its more valuable relative. In fact, we see the boar fish, *Capros aper*, first recorded as British in 1825, and considered useless as food, has now become so abundant in places as to prove a perfect pest; the trawlers along the south-west coast having been obliged to change their ground in order to get out of their way. Such immense numbers sometimes obtain entrance into the trawl, that holes have to be cut in order to allow them to escape, as it has been found almost impossible to lift such a bulk on deck without carrying away the gear.

One argument adduced against legislating in fisheries hardly coincides with the lessons we learn when investigating the food of the finny tribes. We are told that legislation would be interfering with the "balance of nature," which if left alone would surely eventuate in the "survival of the fittest." Such an argument cannot hold good respecting fresh-water fisheries in populated districts, where man, unchecked by wholesome restrictions, not only can, but does, ruin fisheries. Can it be advanced that the balance of nature is left unchanged when man commences to fish the sea with the sole desire to obtain all he is able? This cannot be, for in the open waters he kills his millions of mackerel and herring which he requires as food, but he takes little or no notice of the sharks and dog-fishes which prey upon them, and are left to multiply, protection being practically obtained by them due to the little use their bodies are to man. Is not this mode of fishing destroying the balance which I hold exists wherever nature and nature's works are left entirely to nature's laws, unaltered by the advent of predaceous man, but his rapacity at once changes the normal conditions. Many of us must have been struck by the instance adduced a short time since by Sir Lyon Playfair, who, while arguing against regulating fisheries, observed that we cannot alter the balance of nature without causing mischief. He informed us that it was within the sphere of his personal knowledge on the west coast of Scotland, where fishermen for some cause were not plying their occupation, that predaceous fishes were depleting the breeding beds of the herring. Here leaving the balance of nature to itself appears (according to Sir L. Playfair's views) to have resulted in a loss to the fisheries, but he argued that the fishermen should be permitted to catch fishes all the year round. In fact, he obtained, as a result of his observation, a regulation that herrings ought not to be left alone at the breeding season, and consequently they were fished subsequently at this time of the year with the most favourable results. If facts and results were as given, one would have imagined this advent of man on the scene would have been an interference with nature, but we are on the contrary assured that unaided nature, unable to maintain the requisite balance, had to be assisted by the fisherman, and then, and not until then, all went well.

Gulls and sea-birds which prey upon herrings are protected by law; the young herrings have now no protection, but are being consumed wholesale in our land, and no young are being raised by man's artificial means to replace the destruction caused by man. Our inshore fisheries are being depleted, is the assertion around our coasts; and whether this is due to absence of food or immoderate destruction of immature fish has still to be ascertained by a judicious investigation carried out as in the United States. Without giving any opinion on the cause of this depletion, I would suggest that instead of raising a cry against the price of fish, a more probable road for inquiry would be into the state of our sea fisheries, and whether any, and if so by what restrictions, or by what means they can be restored to their original abundance, and afford a cheap and wholesome food to the teeming millions of these isles.

DISCUSSION.

Professor **Brown Goode** moved a vote of thanks to Dr. Day for the very interesting and satisfactory paper he had read, which he had no hesitation in saying was the most philosophic and comprehensive treatise on the subject which had yet been prepared. He had referred to the studies which had been made in the United States on the food of fishes, and on the circumstances which surround fish in their natural homes. He might say from the beginning of the organization of the United States Commission, ten years ago, no subject had commanded more attention than this, because if there were no food there would be no fish, and if the fish which preyed on the useful fishes increased in number sufficiently it was quite evident that man had an evil to contend with in the capture of those useful fishes whom he could not hope to equal in any way. The food of fish was of great importance both to the fishermen and to the fish culturist. The fisherman by his careful observation of the habits of fish was able to pursue them to much better advantage. He had seen a great deal of fishermen for the last ten years, and many of them were natural observers of great ability. They waited the appearance of the schools of swarming crabs and shrimps, and other little fish on which the large fish preyed, and by the study of these animals shaped the course of their vessels and selected their fishing grounds, and not only so, but selected their bait also. A skilful fisherman always tried to give the fish he was trying to catch a bait corresponding to that they were feeding on naturally at the time. At the cod fishery of Labrador the bait used was almost entirely capling, because at that time the cod would take hardly any other bait. On the coast of Norway the same thing occurred; but when they went on the Grand Banks to fish they used herring because herring was schooling there in great abundance and the cod would not take anything else. In the winter when fishing off the coast of New England they knew the fish were feeding at the bottom and so they used clams, which were consumed by hundreds of thousands of barrels, the herrings being then almost of no use at all. In this particular region where this fishery of clams was carried on there were acres and acres almost square miles at the bottom covered with beds of clam shells; they were packed like little nests of Japanese wooden trays, and evidently the cod fish had swallowed the clams five and six at the time, digested off the contents, and the shells had been piled up in this way in their stomachs for compactness of stowage and ejected. These clam-shells had been picked up by 100 bushels at the time; but the fishermen also watched the food of the mackerel, and followed them along the coast very largely in advance of their movements. This was principally crustaceæ. They followed the crustaceæ along the coast, not so much by seeing it, because it was too small to be readily seen, but by watching small birds, sea geese as they called them, which fed on these crustaceæ, whenever they noticed them they knew that if they set their bait for mackerel they would be likely to be successful. An interesting point which arose from the observations of fishermen was the relation which different kinds of fish had to each other, and the changes in the distribution of different species depending on this question of food. About twenty years ago mackerel was very abundant in Massachusetts Bay, but suddenly there appeared great shoals of blue fish, fish of, say, 16 to 20 lbs., exceedingly predaceous, which destroyed all other fish in great numbers. That fish which had been absent from the coast for many years made its appearance suddenly round Cape Cod, and before this the mackerel vanished, and the mackerel fishery decreased exceedingly; but at the same time there was a corresponding increase in the lobster fishery. No one knew what to make of it until a very acute old fisherman, Captain Attwood, went to work and studied the subject, and he demonstrated pretty plainly that the absence of the mackerel had had the effect of increasing the number of lobsters, because the mackerel were in the habit of feeding on lobster eggs. The blue fish destroyed the mackerel, and that gave the lobsters a chance to breed. Now the mackerel had come back in great numbers and the balance was more nearly established. Another thing showing the great importance to fishermen of the food of fish was this, that the Manhaden herring, and certain other fish fed on the larvæ, and young shell-fish, crustaceans, which had the peculiar property of heating, as the fishermen said, in their stomachs after it had been caught, so that it was exceedingly difficult to keep them long enough to cure them. In Salem Harbour, where this heating food was particularly abundant, it was the practice of fishermen to pen up the fish for a short time in the nets in order to allow the food to digest before they attempted to cure them. He believed the same thing was practised by Swedish fishermen in the case of the herring. He had mentioned in the Paper he read a few days ago, the circumstance of the change in the habits of the Manhaden herring on the American coast. This was a fish of the utmost importance, some three thousand or four thousand fishing vessels being employed in this fishery, and perhaps a capital of two and a half million dollars. In 1878, for some inscrutable reason, the Manhaden herring disappeared; he had no doubt it was due to a change of temperature, though it was not quite clearly established, and there was a corresponding decrease in the yield of the fisheries. The fish on the coast of Maine were very fat, owing to the fact that they had great sounds to feed in where they could sink down to the bottom and fill their stomachs with the rich bottom ooze; and the fish taken in that region would yield six gallons of oil to one hundred fish. When the temperature barrier excluded them from the Gulf of Maine the fisheries were carried farther down the coast, but it was found that the amount of oil decreased considerably, and the value of the fisheries fell off proportionately. Now within a few days he had received information from two sources that this fish were coming back to the Gulf of Maine in very large numbers; and the fact that they were coming back where they could get food suitable to yield this large amount of oil would be of great importance to the American fishermen, and would no doubt increase the value of their take to something like a million dollars annually.

Professor HUBRECHT, in seconding the vote of thanks, said the question of the food of fishes was of the greatest importance, and at the same time the investigations required were difficult and complicated. It would be gathered from the Paper that it was not so much from kindly attention towards the fish that their appetites were so much considered, but more in order to increase if possible the number, or at least to keep up as far as possible the stock of those useful to man; so that, after all, this inquiry into their food was of rather a selfish character. This was not a very flattering reflection, but still, on the other hand, they might be consoled by remembering that they had also heard from Dr. Day that fishes not only ate their fellows, but also their relatives and even offspring, and therefore it might be considered that when a few fish were caught for the use of man, it would save a great number of others from destruction.

Dr. SPENCER COBBOLD thought it would be a pity that the audience should disperse without some further remarks on this extremely valuable Paper. It had so many bearings, not only those which had been so well spoken of by Professor Goode, but also others which would not be so apparent to a general audience. It would not escape notice that in this Paper it had been stated that small crustaceæ—entomostraca and their allies—formed in many cases the principal basis of the food of fish. Now it so happened that it was these small creatures, when swallowed, performed a function quite apart from that of the nutrition of the fish which swallowed them. There was, he took it, not a single marine or fresh-water crustacean of small size which was not liable itself to entertain or harbour parasites, which must occur in innumerable quantities; but it so happened that all the known parasites, of which there were many thousands, which were obtained from the bodies of fish, gained their entrance to the said fish through food, and that this food was, in nine cases out of ten, if not in ninety-nine out of one hundred, small animals. So curious was this subject, that one single statement of the results of experiment would prove its interest much more than any attempt to grasp a subject of such infinite intricacy.

Professor LEICHEART was anxious to find the cause of parasitism in the salmonidæ. They had in the salmon and trout family a group of parasites with the queer name of Echinorynchi. By experimenting with gameri, he had actually succeeded in rearing with gameri in tanks, in an aquarium, the eggs of parasites which had come from the trout. He had fed these crustaceans with the germs which had come from the salmon and trout family, to such an extent that they actually succumbed from over-infection. There was here, therefore, an instance throwing a clear light on the means of infection of those fishes which formed that family. Now, what obtained in that case obtained in myriads of others, and it would be his business in the communication he had shortly to read, to set forth, in more clear and emphatic terms than he was able to do in those cursory observations, data on which the importance of this